

Figure 1 Overview accomplishment goal criteria

Frameworks	C1	C2	C3	C4	Frameworks	C1	C2	C3	C4	
Menshenin et al. [1]					Küchenhof & Krause [18]					
Ankele et al. [2]					Marzullo et al. [19]					
Castro-Herrera & Cleland-Huang [3]					Schumacher & Feuerstein [20]					
Kain et al. [4]					Dumitrescu et al. [21]					
Haidrar et al. [5]					Heikkilä et al. [22]					
Yip et al. [6]					Lim & Ncube [23]					
Payne Morgan et al. [7]					Albers et al. [24]					
Madni [8]					Choi et al. [25]					
O'Sullivan & Sheahan [9]					Restrepo et al. [26]					
Zhang et al. [10]					Redante et al. [27]					
Wood et al. [11]					Haukipuro & Arhippainen [28]					
Golkar & Crawley [12]					Gürtler & Lindemann [29]					
Kwok & Lau [13]					Preutenborbeck et al. [30]					
Saravi et al. [14]					Panchal [31]					
Parets-Llorca & Grunbacher [15]					Horn et al. [32]					
Pezzotta et al. [16]					Schneberger et al. [33]					
Fakhfakh et al. [17]					Papavasiliou & Gorod [34]					

Goal of the framework	Key focus
C1: Consideration and Traceability of Stakeholder Needs in the PDP	Ensuring that stakeholder needs are consistently incorporated and traceable throughout the PDP
C2: Stakeholder Communication and Feedback	Outlining how, when and through which channel communication should be established
C3: Stakeholder Identification and Selection	Who should and shouldn't be involved to which level
C4: Requirements Identification in the Early Phase of Product Development	Focus on eliciting requirements and facilitating the engagement

References

- [1] Menshenin Y, Mordecai Y, Crawley EF, et al. Model-Based System Architecting and Decision-Making. In: Madni AM, Augustine N, Sievers M, editors. *Handb. Model-Based Syst. Eng.*, Cham: Springer International Publishing; 2023, p. 289–330. https://doi.org/10.1007/978-3-030-93582-5_17.
- [2] Ankele D, Duehr K, Albers A, et al. Stakeholderbeteiligung im Sprint Review bei der agilen Produktentwicklung mechatronischer Systeme. ResearchGate, 2023.
- [3] Castro-Herrera C, Cleland-Huang J. A Machine Learning Approach for Identifying Expert Stakeholders. 2009 Second Int. Workshop Manag. Requir. Knowl., 2009, p. 45–9. <https://doi.org/10.1109/MARK.2009.1>.
- [4] Kain AS, Kirschner RJ, Lindemann U, et al. Innovation Networks – Approaches to Derive Nodes and Edges Systematically. 58-6 Proc ICED 09 17th Int Conf Eng Des Vol 6 Des Methods Tools Pt 2 Palo Alto CA USA 24-27082009 2009:111–22.
- [5] Haidrar S, Anwar A, Roudies O. A SYSML-Based Approach to Manage Stakeholder Requirements Traceability. 2017 IEEEACS 14th Int. Conf. Comput. Syst. Appl. AICCSA, 2017, p. 202–7. <https://doi.org/10.1109/AICCSA.2017.183>.
- [6] Yip MH. Mapping stakeholder engagement needs in early-stage system development process. Proc Des Soc 2023;3:2565–74. <https://doi.org/10.1017/pds.2023.257>.
- [7] Payne Morgan A, Howell BF, Kilbourn-Barber G. Co-Design and artificial intelligence: A method to empower end-users in visual communication. 131 Proc. Int. Conf. Eng. Prod. Des. Educ. EPDE 2024, 2024, p. 557–62. <https://doi.org/10.35199/EPDE.2024.94>.
- [8] Madni AM. Expanding Stakeholder Participation in Upfront System Engineering through Storytelling in Virtual Worlds. Syst Eng 2015;18:16–27. <https://doi.org/10.1002/sys.21284>.
- [9] O’Sullivan M, Sheahan C. Reimagining and democratising the new product development process through a board game analogy. 95 Proc. 21st Int. Conf. Eng. Prod. Des. Educ. EPDE 2019 Univ. Strathclyde Glasg. 12th -13th Sept. 2019, 2019. <https://doi.org/10.35199/epde2019.80>.
- [10] Zhang Z, Liu J, Evans RD, et al. A Design Communication Framework Based on Structured Knowledge Representation. IEEE Trans Eng Manag 2021;68:1650–62. <https://doi.org/10.1109/TEM.2020.3002648>.
- [11] Wood J, Sarkani S, Mazzuchi T, et al. A framework for capturing the hidden stakeholder system. Syst Eng 2013;16:251–66. <https://doi.org/10.1002/sys.21224>.
- [12] Golkar A, Crawley EF. A Framework for Space Systems Architecture under Stakeholder Objectives Ambiguity. Syst Eng 2014;17:479–502. <https://doi.org/10.1111/sys.21286>.
- [13] Kwok SY, Hallstedt SI. Towards Strategic Sustainable Product Development: Challenges and Opportunities for Communicating Sustainability in a Value Chain. 91 Proc. Nord. 2018 Linköping Swed. 14th - 17th August 2018, 2018.
- [14] Saravi S, Joannou D, Kalawsky RS, et al. A Systems Engineering Hackathon – A Methodology Involving Multiple Stakeholders to Progress Conceptual Design of a Complex Engineered Product. IEEE Access 2018;6:38399–410. <https://doi.org/10.1109/ACCESS.2018.2851384>.
- [15] Parets-Llorca J, Grunbacher P. Capturing, negotiating, and evolving system requirements: bridging WinWin and the UML. Proc. 25th EUROMICRO Conf. Inform. Theory Pract. New Millenn., vol. 2, 1999, p. 252–9 vol.2. <https://doi.org/10.1109/EURMIC.1999.794788>.
- [16] Pezzotta G, Cavalieri S, Romero D. Collaborative product-service systems engineering: Towards an active role of customers and stakeholders in value co-creation. 2017 Int. Conf. Eng. Technol. Innov. ICEITMC, 2017, p. 1247–54. <https://doi.org/10.1109/ICE.2017.8280023>.
- [17] Fakhfakh S, Jankovic M, Hein AM, et al. Early stakeholder modeling and analysis: New mobility services (Product Service Systems of Systems). Syst Eng 2024;27:449–65. <https://doi.org/10.1002/sys.21728>.
- [18] Küchenhof J, Krause D. Entwicklung eines Produktarchitekturmodells zur Ableitung modularer Produktstrukturen. 98 Proc 30th Symp Des X DFX 2019 2019:25–36. <https://doi.org/10.35199/dfx2019.3>.

- [19] Marzullo D, Di Gironimo G, Dongiovanni DN, et al. Iterative and Participative Axiomatic Design Process to Improve Conceptual Design of Large-Scale Engineering Systems. In: Rizzi C, Andrisano AO, Leali F, et al., editors. *Des. Tools Methods Ind. Eng.*, Cham: Springer International Publishing; 2020, p. 492–505. https://doi.org/10.1007/978-3-030-31154-4_42.
- [20] Schumacher J, Feurstein K. Living Labs - the user as co-creator. 2007 IEEE Int. Technol. Manag. Conf. ICE, 2007, p. 1–6.
- [21] Dumitrescu R, Bremer C, Kühn A, et al. Model-based development of products, processes and production resources: A state-oriented approach for an integrated system model of objects, processes and systems. - *Autom* 2015;63:844–57. <https://doi.org/10.1515/auto-2015-0014>.
- [22] Heikkila V, Jadallah A, Rautiainen K, et al. Rigorous Support for Flexible Planning of Product Releases - A Stakeholder-Centric Approach and Its Initial Evaluation. 2010 43rd Hawaii Int. Conf. Syst. Sci., 2010, p. 1–10. <https://doi.org/10.1109/HICSS.2010.323>.
- [23] Lim SL, Ncube C. Social networks and crowdsourcing for stakeholder analysis in system of systems projects. 2013 8th Int. Conf. Syst. Syst. Eng., 2013, p. 13–8. <https://doi.org/10.1109/SYSoSE.2013.6575235>.
- [24] Albers A, Kubin A, Eckhardt A, et al. Systems-Engineering-based Requirements Reuse in Accordance with Stakeholder Needs in Automotive Product Development. 2022 IEEE Int. Symp. Syst. Eng. ISSE, 2022, p. 1–8. <https://doi.org/10.1109/ISSE54508.2022.10005513>.
- [25] Choi SC, Suh ES, Park CJ. Value chain and stakeholder-driven product platform design. *Syst Eng* 2020;23:312–26. <https://doi.org/10.1002/sys.21527>.
- [26] Restrepo J, McAlloone TC, Schlegel T, et al. A user-centered approach to developing emergent technology products. 48 Proc Des 2008 10th Int Des Conf Dubrov Croat 2008:483–92.
- [27] Redante RC, De Medeiros JF, Vidor G, et al. Creative approaches and green product development: Using design thinking to promote stakeholders' engagement. *Sustain Prod Consum* 2019;19:247–56. <https://doi.org/10.1016/j.spc.2019.04.006>.
- [28] Haukipuro L, Arhippainen L. Guidelines for Facilitating User-Centric Product and Service Development in an Open Innovation Environment. 2019 25th Conf. Open Innov. Assoc. FRUCT, 2019, p. 123–30. <https://doi.org/10.23919/FRUCT48121.2019.8981495>.
- [29] Gürtler MR, Lindemann U. Situative open innovation - A model for selecting the right external actors and involving them in an efficient way. *Proc Int Conf Eng Des ICED 2013;3 DS75-03:259–68*.
- [30] Preutenborbeck M, Wolf-Monheim F, Carey E, et al. Stakeholder-driven Design and Exploration of Sociotechnical Systems using Virtual-Reality. *Procedia CIRP* 2024;128:274–9. <https://doi.org/10.1016/j.procir.2024.04.006>.
- [31] Panchal JH. Using crowds in engineering design - towards a holistic framework. 80-8 Proc 20th Int Conf Eng Des ICED 15 Vol 8 Innov Creat Milan Italy 27-300715 2015:041–50.
- [32] Horn J, Moencks M, Roth E, et al. Voice of the Workforce: Integrating the Workforce's Perspective on Operator Assistance Systems into Human-centric Production. 2022 IEEE Int. Conf. Ind. Eng. Eng. Manag. IEEM, 2022, p. 0112–6. <https://doi.org/10.1109/IEEM55944.2022.9989950>.
- [33] Schneberger J-H, Kaspar J, Vielhaber M. Integrated and Customer-Oriented Material and Process Selection by Sensory Multi-Criteria Decision-Making. 94 Proc. Des. Soc. 22nd Int. Conf. Eng. Des. ICED19, 2019. <https://doi.org/10.1017/dsi.2019.123>.
- [34] Papavasiliou S, Gorod A. Stakeholder Management in Digital Transformation: A System of Systems Approach. 2022 17th Annu. Syst. Syst. Eng. Conf. SOSE, 2022, p. 500–5. <https://doi.org/10.1109/SOSE55472.2022.9812667>.